SPIN COATING THEORY

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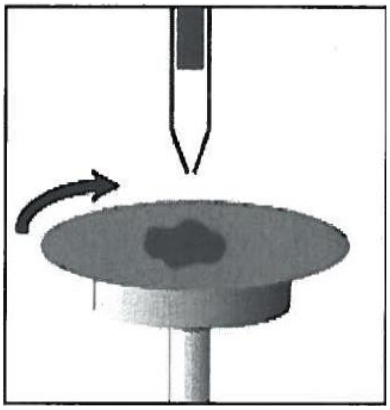
Spin Coating Process Theory

Spin coating has been used for several decades for the application of thin films. A typical process involves depositing a small puddle of a fluid resin onto the center of a substrate a then spinning the substrate at high speed (typically around 3000 rpm). Centripetal acceleration will cause the resin to spread to, and eventually off, the edge of the substrate leaving a thin film of resin on the surface. Final film thickness and other properties will depend on the nature of the resin (viscosity, drying rate, percent solids, surface tension, etc.) and the parameters chosen for the spin process. Factors such as final rotational speed, acceleration, and fume exhaust contribute to how the properties of coated films are defined.



One of the most important factors in spin coating is repeatability. Subtle variations in the parameters that define the spin process can result in drastic variations in the coated film. The following is an explanation of some of the effects of these variations.

Spin Coating Process Description

A typical spin process consists of a dispense step in which the resin fluid is deposited onto the substrate surface, a high-speed spin step to thin the fluid, and a drying step to eliminate excess solvents from the resulting film. Two common methods of dispense are Static dispense, and Dynamic dispense.

Static dispense is simply depositing a small puddle of fluid on or near the center of the substrate. This can range from 1 to 10 CC depending on the viscosity of the fluid and the size of the substrate to be coated. Higher viscosity and or larger substrates typically re-quire a larger puddle to ensure full coverage of the substrate during the high-speed spin step.

Dynamic dispense is the process of dispensing while he substrate is turning at low speed. A speed of about 500 RPM is commonly used during this step of the process. This serves to spread the fluid over the substrate and can result in less waste of resin material since it is usually not necessary to deposit as much to wet the entire surface of the substrate. This is a particularly advantageous method when the fluid or substrate itself has poor wetting abilities and can eliminate voids that may otherwise form.

After the dispense step it is common to accelerate to a relatively high speed to thin the fluid to near its final desired thickness. Typical spin speeds for this step range from 1500-6000 RPM,

again depending on the properties of the fluid as well as the substrate. This step can take from 10 seconds to several minutes. The combination of spin speed and time selected for this step will generally define the final film thickness. In general, higher spin speeds and longer spin times create thinner films. The spin coating process involves a large number of variables that tend to cancel and average out during the spin process and it is best to allow sufficient time for this to occur. A separate drying step is sometimes added after the high speed spin step to further dry the film without substantially thinning it. This can be advantageous for thick films since long drying times may be necessary to increase the physical stability of the film before handling. Without the drying step, problems can occur during handling, such as pouring off the side of the substrate when removing it from the spin bowl. In this case, a moderate spin speed of about 25% of the high-speed spin will generally suffice to aid in drying the film without significantly changing the film thickness. Each program on a spin coater may contain up to ten separate process steps. While most spin processes require only two or three, this allows the maximum amount of flexibility for complex spin coating requirements.

Spin Speed

Spin speed is one of the most important factors in spin coating. The speed of the substrate (RPM) affects the degree of radial (centrifugal) force applied to the liquid resin as well as the velocity and characteristic turbulence of the air immediately above it. In particular, the high-speed spin step generally defines the final film thickness. Relatively minor variations of ±50 RPM at this stage can cause a resulting thickness change of 10%. Film thickness is largely a balance between the force applied to shear the fluid resin towards the edge of the substrate and the drying rate, which affects the viscosity of the resin. As the resin dries, the viscosity increases until the radial force of the spin process can no longer appreciably move the resin over the surface. At this point, the film thickness will not decrease significantly with increased spin time. All spin coating systems are specified to be repeatable to within ±5 RPM at all speeds. Typical performance is ±1 RPM. In addition, all programming and display of spin speed is given with a resolution of 1 RPM.

Acceleration

The acceleration of the substrate towards the final spin speed can also affect the coated film properties. Since the resin begins to dry during the first part of the spin cycle, it is important to accurately control acceleration. In some processes, 50% of the solvents in the resin will be lost to evaporation in the, first few seconds of the process.

Acceleration also plays a large role in the coat properties of patterned substrates. In many cases, the substrate will retain topographical features from previous processes; it is therefore important to uniformly coat the resin over and through these features.

While the spin process in general provides a radial (outward) force to the resin, the acceleration provides a twisting force to the resin. This twisting aids in the dispersal of the resin around topography that might otherwise shadow portions of the substrate from the fluid. Acceleration

of spinners is programmable with a resolution of 1 RPM/second. In operation, the spin motor accelerates (or decelerates) in a linear ramp to the final spin speed.

Fume Exhaust Time

The drying rate of the resin fluid during the spin process is defined by the nature of the fluid itself (volatility of the solvent systems used) as well as by the air surrounding the substrate during the spin process. Just as a damp cloth will dry faster on a breezy dry day than during damp weather, the resin will dry depending on the ambient conditions around it. It is well known that such factors as air temperature and humidity play a large role in determining coated film properties. It is also very important that the airflow and associated turbulence above the substrate itself be minimized, or at least held constant, during the spin process.

SPIN COATING PROCESS TROUBLESHOOTING

Spin coater

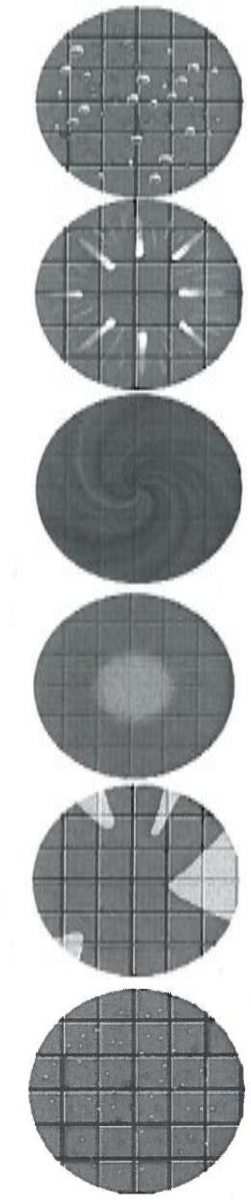
As explained previously, there are several major factors affecting the coating process. Among these are spin speed, acceleration, spin time and exhaust. Process parameters vary greatly for different resin materials and substrates so there are no fixed rules for spin coat processing, only general guidelines. Following is a list of issues to consider for specific process problems.

Film too thin

Spin speed too high	Select lower speed
Spin time too long	Decrease time during high-speed step
Inappropriate choice of resin material	Contact resin manufacturer

Film too thick

Spin speed too low	Select higher speed
Spin time too short	Increase time during high-speed step
Exhaust volume too high	Adjust exhaust lid or house exhaust damper
Inappropriate choice of resin material	Contact resin manufacturer



Air bubbles on wafer surface

Air bubbles in dispensed fluid (resin)
Dispense tip is cut unevenly or has burrs or defects

Comets, streaks or flares

Fluid velocity (dispense rate) is too high
Spin bowl exhaust rate is too high
Resist sits on wafer too long prior to spin
Spin speed and acceleration setting is too high
Particles exist on substrate surface prior to dispense
Fluid is not being dispensed at the center of the substrate surface

Swirl pattern

Spin bowl exhaust rate is too high
Fluid is striking substrate surface off center
Spin speed and acceleration setting is too high
Soin time too short

Center circle (Chuck Mark)

If the circle is the same size as the spin chuck, switch to a Delrin spin chuck

Uncoated Areas

Insufficient Dispense Volume

Pinholes

Air bubbles
Particles in fluid
Particles exist on substrate surface prior to dispense

Poor reproducibility

Variable exhaust or ambient conditions	Adjust exhaust lid to fully closed
Substrate not centered properly	Center substrate before operation
Insufficient dispense volume	Increase dispense volume
Inappropriate application of resin material	Contact resin manufacturer
Unstable balance in speed/time parameters	Increase speed/decrease time or vice versa

Poor film quality

Exhaust volume too high	Adjust exhaust lid or house exhaust damper
Acceleration too high	Select lower acceleration
Unstable balance in speed/time parameters	Increase speed / decrease time or vice versa
Insufficient dispense volume	Increase dispense volume
Inappropriate application of resin material	Contact resin manufacturer